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Effect of Gibberellic Acid on the Growth and Yield of Groundnut (*Arachis hypogaea* L.)

(Kesan Asid Giberelik pada Pertumbuhan dan Penghasilan Kacang Tanah (*Arachis hypogaea* L.))

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ABSTRACT

*This study was conducted during two different seasons to determine the best concentration of gibberellic acid (GA3) that could result in better growth and higher yield of groundnut (*Arachis hypogaea *L.). Experiments were conducted during the 2015 dry season and 2016 wet season at the field of the Universiti Kebangsaan Malaysia (UKM), Bangi, Selangor, Malaysia. The purpose of the experiments was to investigate the response of the groundnut plants to four levels of GA3 (0, 50, 100 and 150 mg L^{-1}) as foliar spray at 21 and 42 days after sowing. The treatments were laid out in a randomized complete block design and replicated thrice. The results showed that the treatment of 150 mg L^{-1} GA3 significantly (*p*<0.05) increased plant height, number of branches per plant, total dry weight, number of pods per plant, pod yield, 100 seed weight, % shelling, oil content, protein content, seed moisture and germination percentage during the wet and dry seasons. In conclusion, the 150 mg L^{-1} GA3 concentration is the optimum level required to enhance the growth and yield in groundnuts during the wet and dry seasons.*

Keywords: Dry season; GA3; gibberellic acid; groundnut; wet season

ABSTRAK

*Kajian ini dijalankan dalam dua musim yang berbeza bagi mencari kepekatan asid giberelik (GA3) yang terbaik untuk menghasilkan pertumbuhan yang lebih baik dan hasil yang lebih tinggi bagi kacang tanah (*Arachis hypogaea *L.). Kajian dilakukan ketika musim kemarau pada tahun 2015 dan musim hujan tahun pada 2016 di ladang Universiti Kebangsaan Malaysia (UKM), Bangi, Malaysia. Tujuan kajian ini adalah untuk mengkaji tindak balas tumbuhan kacang tanah terhadap empat peringkat GA3 (0, 50, 100 dan 150 mg L^{-1}) sebagai semburan daun pada hari ke-21 dan ke-42 selepas penyemaian. Perlakuan tersebut telah ditetapkan dalam reka bentuk blok lengkap rawak dengan tiga replikasi. Keputusan kajian menunjukkan bahawa perlakuan dengan 150 mg L^{-1} GA3 nyata sekali (*p*<0.05) meningkatkan ketinggian tumbuhan, bilangan dahan setiap tumbuhan, bilangan nodul setiap tumbuhan, jumlah berat kering, bilangan lenggai setiap tumbuhan, hasil lenggai, berat 100 biji benih, % pengasingan cangkerang, kandungan minyak, kandungan protein, kelembapan biji benih dan peratus percambahan semasa musim hujan dan kemarau. Walau bagaimanapun, analisis regresi menunjukkan bahawa 150 mg L^{-1} GA3 yang digunakan semasa musim hujan dan musim kemarau adalah pada tahap optimum yang diperlukan untuk memangkin pertumbuhan dan hasil kacang tanah.*

Kata kunci: Asid giberelik; GA3; kacang tanah; musim hujan; musim kering

INTRODUCTION

Peanut or groundnut (*Arachis hypogaea* L.) is an important food crop dispersed in subtropical and tropical zones worldwide. It is an essential source for livestock fodder because of its protein content and edible oil. No specified growth habit has been found for groundnut plants. Therefore, growth and evolution of the reproductive and vegetative organs overlap (Verma et al. 2009).

Specific physiological processes in plants can be modified by organic compounds that are present as plant regulators and generally they do not operate alone. A physiological effect is produced when two or more of these compounds act together. Moreover, the growth regulators can help in dominating the forte of the physiological source by enhancing chlorophyll production (Wareing et al. 1968). Plant growth regulators (PGAs) support the development and production processes in crops (Kamuro et al. 2001; Samsuzzaman 2004). Some processes of plant growth, such as seed germination in common bean, cotton plants and soybean, are controlled by gibberellic acid (GA3), which is a plant growth regulator (Maske et al. 1997).

Root development processes, such as increment or deterrence of root elongation as well as fruit or flower development, can be controlled by PGAs (Yamaguchi & Kamiya 2000). Low concentration and small quantities of GA3, a phytohormone, is essential to hasten the growth and development of plants. Hence, positive conditions may be created by applying a growth regulator (GA3) at the correct concentration and at the stipulated time for a particular plant crop (Meera & Poonam 2010). Various studies/experiments have made use of this growth promoter to increase and develop the embryo in various species. Thus, the utilization of the growth regulator GA3 will help boost the production of seeds in *Arachis*.

Researchers have confirmed that various synthetic and natural growth regulators help in hastening seed germination and improving seedling vigor of a number of crops (Mohanty & Sahoo 2000; Renugadevi & Vijayageetha 2006). In recent time, Verma et al. (2009) described the part played by a few PGRs in various physiological parameters of crops that could influence the productivity in groundnut (of the semi-spreading habit). Mukhtar and Singh (2006) reported that GA3 enhanced grain yield, pod maturity, flowering, and growth in cowpea plants.

Determining the optimal concentration of GA3 that could increase the growth and yield components of groundnut during the wet and dry seasons under Malaysian conditions is necessary. The current research was undertaken in order to search and determine a suitable concentration of GA3 for augmenting groundnut production.

Materials and Methods

STUDY AREA

Field experiments were conducted during the 2015 dry season and 2016 rainy season at the Universiti Kebangsaan Malaysia field (2°55’13.1”N 101°47’01.4”E) situated at the Faculty of Science and Technology, Universiti Kebangsaan Malaysia, Malaysia. The total rainfall recorded during the wet and dry seasons were 350-500 mm and less than 200 mm, respectively. The dry season occurs from May to September and the wet season from October to April annually. The mean annual temperature ranges at 28-31°C (Malaysian Meteorological Department 2016). Soil samples were randomly collected from depths of 0-30 cm using an auger from 10 different locations within the study area. The soil samples were air dried, sieved, and then analyzed for physical and chemical properties according to the method described by Jackson (1973) (Table 1).

EXPERIMENTAL DESIGN

The experimental field was cleared, ploughed, harrowed twice and ridged. Plots of 3 × 3 m were marked in accordance with the field plan. Alleys of 1.0 m between plots were built along the ridges and each plot was made up of four rows. The groundnut (*A. hypogaea*) seeds were obtained from the Malaysian Agricultural Research and Development Institute (MARDI), Serdang, Selangor, Malaysia. The seeds were grown at 75 × 25 cm inter- and intra-row spacing, with two seeds planted per hole. A fertilizer dosage of 27 kg N, 55 kg P_2O_5 and 45 kg K_2O per hectare was applied at the time of sowing. The experimental design was a complete randomized complete block with three replications.

TABLE 1. Initial physical and chemical properties of the experimental soil for dry and rainy seasons

Parameters	Dry season	Wet season
pH	4.57	4.83
CEC meq/100 g soil	3.8	4.15
Soil moisture (%)	10.247	12.601
Organic matter (%)	5.6	6.15
Ca^{2+} (μg/g)	431.39	420.73
Mg^{2+} (μg/g)	320.187	346.210
K^+ (μg/g)	783.13	730.67
Phosphorus (μg/g)	40.583	38.428
silt (%)	7.34	5.31
clay (%)	17.25	19.07
sand (%)	75.41	75.62
Nitrate (μg/g)	17.5	18.4
Texture	Sandy clay	Sandy clay

EXPERIMENTAL PROCEDURE

The treatments included four concentrations of GA3, namely, 0, 50, 100 and 150 mg L^{-1}. The different GA3 concentrations were prepared by dissolving 0.51, 1.02 and 1.53 g GA3 powder in 10 L water for the concentrations of 50, 100 and 150 mg L^{-1}, respectively. Each concentration was sprayed on the groundnut foliage for the respective treatments at 21 and 42 days after sowing. Weeding was done with a hand hoe at full seedling emergence and at four weeks after sowing. Harvesting was carried out when the pods were fully mature. The soil was loosened and the plants were uprooted using a hoe. The pods were allowed to dry before detaching from the plant.

DATA COLLECTION AND ANALYSIS

The plant samples were collected during the harvest stage (115 days after sowing) and the data on the crop growth and yield were recorded. Measurements on growth parameters included plant height, number of branches per plant, number of nodules per plant, and total dry matter production. The yield parameters included number of unfilled pods per plant, number of pods per plant, pod yield (kg ha^{-1}), seed weight, shelling percentage, oil content, protein content and germination.

The statistical analysis of data on growth and yield was done using the analysis of variance technique. Significance of the differences among treatment effects was tested using the ‘F’ test. Significance was accepted at $p \leq 0.05$.

Results

EFFECT OF GA3 ON GROWTH PARAMETERS

Various concentrations of GA3 had significant effects on the height of the plant (Table 2). The tallest plant height (75 cm) was obtained from the treatment of 150 mg L^{-1} GA3, which was applied during the dry season. The results

TABLE 2. Effects of the application of different concentrations of GA3 on groundnut growth

	Plant height (cm)		Number of branch plant^{-1}		Number of nodules plant^{-1}		Dry weight plant $^{-1}$	
GA3 levels (mg L^{-1})	Dry S.	Wet S.	Dry S.	Wet S.	Dry S.	Wet S.	Dry S.	Wet S.
control	62.6	60	16.1	13	63	63	45	47.2
50	69.0	68	19.3	18	58	60	57	60.8
100	70.0	66	22.8	19	46	57	60	61.2
150	75.0	71	28.3	23	45	51	66	61.5
LSD value	8.45 *	6.74 *	6.92 *	3.48 *	6.75 *	5.77 *	7.63 *	7.02 *

*significant at 5% level of significant; S._ season

were not statistically different during the wet season as the height of 71 cm was obtained for the application of GA3 at 150 mg L^{-1}. The height of the shortest plant (60 cm) was recorded for the control treatment. The application of various concentrations of GA3 significantly increased the number of branches per plant in the wet and dry seasons. The 150 mg L^{-1} GA3 treatment gave a considerably higher number of branches per plant (28.3 and 23) compared with that of the control with 0 mg L^{-1} (16.1 and 13 branches) (Table 2).

Furthermore, the application of varying concentrations of GA3 affected the number of nodules per plant. The maximum quantity of nodules per plant (63) was obtained for 0 mg L^{-1} GA3 (control) in the wet and dry seasons, and the minimum quantity of nodules per plant (45 and 51 for the wet and dry seasons, respectively) was observed for 150 mg L^{-1} GA3 (Table 2). The total dry weight of each of the groundnut plants differed significantly with the application of varying concentrations of GA3. The maximum dry weight per plant in the dry and wet seasons (66 and 61.5 g per plant, respectively) was obtained from the plots treated with 150 mg L^{-1}GA3, whereas the lowest dry weight per plant (45 and 47.2 g per plant, respectively) was recorded in the control treatments (Table 2).

EFFECT GA3 ON YIELD PARAMETERS

The number of pods per plant was significantly affected by varying concentrations of GA3 (Table 3). The maximum number of pods per plant in the dry and wet seasons (30 and 23, respectively) was obtained from the plots sprayed with 150 mg L^{-1} GA3, and the lowest number of pods (14) was obtained from the control plots in the wet season. The effects of different concentrations of GA3 on the yield of groundnut are presented in Table 3. The highest dosage of GA3 (150 mg L^{-1}) gave the highest pod yield in both the wet and dry seasons.

Moreover, the weight of 100 groundnut seeds varied significantly because of the use of different concentrations of GA3. The maximum weight of 100 seeds (51.3 and 46.2 g) was obtained from the plots sprayed with 150 mg L^{-1} GA3 in the dry and wet seasons. The lowest weight of 100 seeds (40.6 g) was recorded in the control plots during the wet season (Table 3). A significant variance was noticed for the shelling percentage caused by the application of different concentrations of GA3. The lowest shelling percentage (43.2% and 50.7% for the dry and wet seasons, respectively) was recorded from the plots sprayed with 150 mg L^{-1} GA3, whereas the highest shelling percentage (59.8%) was obtained from the control during the wet season (Table 3).

EFFECT OF GA3 ON SEED QUALITY

The oil content improved significantly because of the use of increased GA3 concentrations (Table 4). For both seasons, the minimum oil content (45.3% and 41.3%) was obtained from the control plots G_0 (0 mg L^{-1}) of dry season and G_1 (50 mg L^{-1}) of wet season, while the maximum oil content (54.3% and 49.2%) was recorded from the treatment G_3 (150 mg L^{-1}). The protein content varied significantly because of the use of different GA3 concentrations (Table 4). In the wet and dry seasons, the maximum protein content (26.9% and 25.6%, respectively) was recorded at G_3 (150 mg L^{-1}), and the minimum protein content (19.3%) was obtained from the control G_0 (0 mg L^{-1}).

TABLE 3. Effects of the application of GA3 at different concentrations on groundnut yield

GA3 levels (mg L^{-1})	Number of filled pods		Number of unfilled pods		Number of pods plant^{-1}		Pod yield (kg ha^{-1})		100 seed (g)		Shelling %	
	Dry S.	Wet S.	Dry S.	Wet S.	Dry S.	Wet S.	Dry S.	Wet S.	Dry S.	Wet S.	Dry S.	Wet S.
control	14	11	4	5	17	14	2280	2067	42.1	40.6	58.6	59.8
50	18	13	6	4	22	19	2330	2142	44.5	41.2	55.1	58.9
100	20	16	5	3	24	19	2420	2208	46.3	45.1	52.4	54.3
150	28	21	2	3	30	23	2610	2439	51.3	46.2	43.2	50.7
LSD value	6.55 *	5.24 *	2.69 *	2.18 NS	6.83 *	5.85 *	178.4 *	188.9 *	7.53 *	3.72 *	6.99 *	5.63 *

*significant at 5% level of significant; S._ season

TABLE 4. Effects of the application of GA3 at different concentrations on groundnut seeds quality

GA3 levels (mg L^{-1})	Oil content %		Protein content %		Seed moisture %		Germination %	
	Dry S.	Wet S.	Dry S.	Wet S.	Dry S.	Wet S.	Dry S.	Wet S.
control	45.3	45.9	20.1	19.3	5.5	5.1	62	58
50	47.2	41.3	22.4	20.6	6.7	7.3	72	77
100	49.1	46.7	23.4	21.5	6.9	7.8	79	74
150	54.3	49.2	25.6	26.9	7.9	8.6	91	84
LSD value	5.42 *	4.85 *	3.28 *	4.62 *	1.33 *	2.14 *	8.64 *	8.67 *

*significant at 5% level of significant; S._season

On the other hand, the moisture content of the seed was significantly affected by varying GA3 concentration. The highest seed moisture content was found in the treatments with 150 mg L^{-1} (8.6%) GA3 during the wet season and (7.9%) the dry season; the lowest seed moisture content was observed in the control during the wet season (5.1%) and dry season (5.5%) (Table 4). The germination percentage was also significantly affected by the different concentrations of GA3. The maximum germination percentage (91%) was obtained from the plots sprayed with 150 mg L^{-1} GA3 concentration in the dry season and 84% during wet season. The minimum germination percentage (58%) was recorded from the control plot (Table 4).

Discussion

In the present investigation, GA3 was applied at two physiologically delicate development stages, namely 21 to 42 days after planting. The use of 150 mg L^{-1} GA3 greatly affected the intensity of physical growth formation. Under these conditions, parameters of growth, such as plant height, number of branches, number of nodes and dry weight has increased. The improvement in plant growth because of the use of GA3 might be attributed to cell elongation and cell division. GA3 influences the action of various enzymes, particularly amylase and enhances the movement of starch particles in the cotyledons, consequently triggering growth.

These results are in accordance with the findings of Maekawa et al. (2009), in which GAs had specific effects on root nodulation in *Lonicera japonica* (Lievens et al. 2005). However, foliar spraying of GA3 caused an improvement in plant height and dry matter generation. Khairul Mazed et al. (2015) confirmed that plant height, number of branches per plant and total dry matter, particularly maximum plant height and dry matter, were obtained from plants that received high GA3 concentrations.

Application of GA3 to groundnut plants improved the yield factors. The enhancement of yield factors is attributed to the role of gibberellic in the improvement of cell elongation and division, internodal elongation, and improvement of cell wall elasticity (Emongor 2007). As observed by Yakubu et al. (2013), during the dry and wet seasons, the pod and kernel produce of groundnut were found to be the highest at the GA3 concentration of 100 mg L^{-1}. The yield of culm was also found to be the highest at the concentration of 100 mg L^{-1} during the dry and wet seasons. Hence, high values of the physio-biochemical, vegetative and yield characteristics of the treated plants are likely to result in high seed yield (Mazid & Naqvi 2014).

As reported by Verma et al. (2009), the number of flowers and pods of the peanut plants increases with treatment of GA3. Hooley (1994) stated that the various types of responses observed in plant cells and tissues when treated with GA3 were primarily because of flower and fruit development, seed reserve mobilization by the aleuronic cells and relative growth in the vegetative tissues. The ability of GA3 to hasten flowering and fruit growth processes by changing the physiological progressions in plants is the inherent cause behind the increased yield of groundnut.

In the present study, GA3 was observed to increase protein content, oil content, seed moisture, and germination percentage in groundnut. Kariali and Mohapatra (2007) reported similar findings, in which GA3 improved the yield of rice. The treatment of plants with GA3 resulted in an increase in the yield, physiological features and yield characteristics of the plants. GA3 also has been reported to improve the protein levels of legumes and increase the yield of chickpea (Meera & Poonam 2010). Emongor and Ndambole (2011) reported that GA3 improved seed quality and yield in cowpea. Pulok et al. (2015) stated that GA3 increased the vigor index and germination percentage of lentils. Similar observations were made by Nikhat et al. (2015) in which different plant attributes, such as oil content, harvest index (HI), oil output per plant and biological yield per plant, were substantially impacted with the increase in GA3 concentration.

Conclusion

The yield of groundnut was greatly improved by foliar spraying of plants with different GA3 concentrations. GA3 at the concentration of 150 mg L^{-1} had significant effect on the growth and yield of groundnut. The findings of the present study will help justify the use of GA3 in groundnut production.

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